REVIEW

# Status on the Scale Development to Measure Water Insecurity Experiences at the Household Level: A Narrative Review

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**ABSTRACT**

Adequate and safe water is critical in promoting all 3 pillars of food security. Hence, ensuring availability of water for all is one of the 2030 Sustainable Development Goals. To monitor progress of this goal and understand the role of water in addressing food insecurity, development of a household-level water insecurity scale has become very critical. As such, using the following concept of water insecurity: *inconsistent access to sufficient amount of safe and clean water for active and healthy life*, several scale development studies have been conducted to measure water insecurity experiences at the household level. Hence, in this review, the science literature was evaluated to *1*) describe the scale development process; *2*) assess the validity results by comparing scale measurements results with the established 4 United Nations (UN) water standards on water access; and *3*) examine key water- and food-related dimensions covered by the scales in measuring water insecurity at the household level. Eight published studies were identified from the following scientific databases: EBSCO, PubMed, Google Scholar, and JSTOR. Five of the 8 selected studies were conducted in sub-Saharan Africa, 2 were conducted in North and South America, and 1 was conducted in South Asia. A majority of the studies were conducted with women and included preliminary qualitative/ethnographic phases to identify scale items. Of the 4 UN water standards, the amount of water used/stored was commonly used to test the scale results. However, no consistent results were found in its association with water insecurity. In a rural setting, distance to water source was positively associated with water insecurity. Psychosocial distress/anxiety and reduced water use for hygiene were key dimensions of scale in all the studies. Rigorous research is needed to establish various levels of water insecurity, its scoring scheme, and its association with daily intake of water—an essential nutrient. *Adv Nutr* 2019;10:864–875.

Keywords: water insecurity, household level, scale validation, hygiene, psychosocial distress, United Nations water standards

## Introduction

The UN endorsed access to clean water as a basic human right in 2010; however, a majority of the world's population is experiencing moderate to severe water shortage (1, 2). According to the latest report on water and sanitation status in developing countries, 2.1 billion people do not have access to potable water at home (3). Approximately 263 million people spend >30 min per round trip collecting water from an improved source, with the situation predicted to get worse by 2025 (3). Smallholder farmers and people living in slums or informal settlements in urban areas are the most affected groups, having very limited access to a safe and consistent source of water (4). In fact, water insecurity, which is generally defined as inconsistent access to a sufficient amount of safe and clean water for active and healthy life, has been a key issue in causing internal conflicts, community displacement, and long-term poverty (4, 5).

### Role of water in achieving food security

Water is critical in sustaining the 3 pillars of food security: food availability, access, and utilization. For instance, agriculture, which produces the necessary energy and nutrients for the world's population, depends on water availability. For smallholder farmers, the land represents their main source of income, and they eat what they grow. Hence, water plays a critical role in predicting their food security status. Farmers living in drought-prone regions, with poor access to water and irrigation resources, are often affected by food insecurity (6).

In terms of food access, both physical and economic access are affected by water in several ways. Because women are generally responsible for fetching and managing water for their households, better access to water allows them to spend

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the maximum time growing food and preparing meals for their households. Studies have shown that home gardening is significantly and directly associated with household food security (7). Consistent availability of water also results in time and money savings, improving households' ability to optimize their diet quality and health (8). Access to water increases opportunities for women to engage in microfinance activities, thereby improving the household budget and food security level (4, 7).

In the case of the third pillar of food security (i.e., food utilization), it is important to recognize that water is an essential nutrient, and meeting its daily requirement is critical to ensure optimal health. Furthermore, water is needed for cooking and improving palatability and digestibility of food. Third, an adequate quantity of potable water is critical for optimal hygiene and prevents food- and water-related illnesses (9). In a meta-analysis of 46 studies, Fewtrell et al. (10) found that improved water supply interventions were effective in reducing water-related illnesses (diarrhea, cholera, and typhoid fever) among children. Recently, the results from the Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development (MAL-ED) study indicate that poor environmental conditions, including inconsistent access to clean water (or water insecurity), can cause poor growth and reduced cognitive development among children through chronic intestinal inflammation and poor absorptive function (11). Hence, in efforts to promote food security and optimal growth among children, use of a sustainable approach of reducing water insecurity is vital.

### Definition of water security and its established environmental indicators

In 2013, UN-Water established the definition of water security as

> the capacity of a population to safeguard sustainable access to adequate quantities of and acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (12).

Furthermore, to promote water security, one of the 2030 Sustainable Development Goals (SDGs) is to "ensure availability and sustainable management of water and sanitation for all" (3). In fact, to monitor and evaluate success in achieving this goal, UN-Water has established 4 standards, and accordingly water access is considered poor when *1*) per capita water use is <50 L/d; *2*) total water collection time exceeds 30 min; *3*) the water source is not within 1000 m of the home; and *4*) water cost exceeds 3% of the household income (2). Establishment of these standards has been a critical first step, and they have been used commonly in monitoring and planning water-related interventions at the community level. Furthermore, the Water Poverty Index has been very useful in measuring water stress and scarcity and its connection to regional- and community-level socioeconomic status and poverty (13). However, to understand the effect of water insecurity on nutritional and health status at the individual level, and drawing upon extensive and well-established literature on the importance of measuring food insecurity at the household level (14, 15), development of validated household-level experiential water (in)security scale is warranted.

### Water insecurity assessment at the household level and its public health implications

Under the general framework of water insecurity referring to inconsistent access to a sufficient amount of safe and clean water for active and healthy life, several studies have been conducted to develop household-level water insecurity scales covering water quantity, quality, and consistency issues at varying levels. In fact, Jepson et al. (16) summarized the use of various socioenvironmental indicators of water insecurity and highlighted the importance of developing a household-level water insecurity scale. Their review provided a clear understanding of the status of the scale development research and highlighted that psychosocial distress is a common phenomenon in water insecurity and occurs cross-culturally. Specifically, their review emphasized that women are most affected by water insecurity, and it is critical to understand the full spectrum of social, economic, and other opportunity costs associated with water insecurity to develop a valid and reliable household-level scale.

To emphasize the importance of water from a nutrition standpoint and its critical role in achieving food security at the household level, our narrative review summarizes the key dimensions of the water insecurity scales developed to date and the extent to which food and water intake-related items are represented in the scales. The 3 objectives of this review are to *1*) describe the scale development process; *2*) assess the validity results by comparing scale measurement results with the established 4 UN-Water standards on water access; and *3*) examine key water- and food-related dimensions covered by the scales in measuring water insecurity at the household level.

## Methods

### Search methods and the process of short-listing articles

As a first step, an extensive literature search was conducted (December 2017 to February 2018) using the following 4 scientific databases: EBSCO, PubMed, Google Scholar, and JSTOR. For each database, we used the following keywords in different combinations: water, security, insecurity, access, scale, diarrhea, validation, measurement, assessment, indicators, household measures, and WASH (water access, sanitation, and hygiene). The search results from each of the 4 databases were imported into EndNote v.8 (Thompson Reuters) to remove duplicates. Next, the following screening criteria were used to short-list the articles: *1*) published in a peer-review journal; *2*) available in English; *3*) published since 2000; and *4*) primary topic of interest is water

assessment at the household level. Specifically, for this fourth criteria, titles and abstracts of the articles were reviewed. Articles focusing on environmental assessment and lacking data at the individual or household level were excluded. Only peer-reviewed articles were retained; conference abstracts, policy briefs, progress reports, and web reports were excluded during this first round of short-listing.

For the next round of iteration, the following eligibility criteria were used: *1*) One of the objectives of the study is to develop and test household-level water insecurity scale; *2*) involve primary data collection at the household level; and *3*) provide clear information on scale items, including length of scale and response options. For this round, specifically, the objectives of the articles were reviewed. If unclear, the full text was read to determine eligibility of the paper for inclusion in the review. Back-referencing was also done during this round to identify potential additional studies for the review.

### Role of authors and information extraction steps

The primary author carried out the initial steps of performing 4 database searches, creating an unduplicated list of articles, and short-listing papers using the initial set of screening criteria. Resulting short-listed papers were independently screened by both of the authors using the next round of eligibility criteria. The results obtained by both of the authors were compared, and a minor discrepancy in the final list of papers for review was resolved using consensus methodology. Extraction of information from each selected study was carried out independently by the authors. Information was extracted into a tabular format and compared, and disagreements between the authors were discussed to reach consensus.

## Results

Using the recommended Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach (17), a summary of the search steps and results is shown in **Figure 1**. From the initial unduplicated list of 1011 articles, 78 articles were short-listed using the initial round of screening criteria. The titles, abstracts, and texts of these 78 articles were then reviewed using the eligibility criteria (Figure 1). Finally, 8 peer-reviewed articles met the criteria and were selected for the review.

Due to differences in formative assessment and validity testing approaches, results from the studies are presented in a stand-alone format and direct comparisons are avoided. The 4 UN-Water standards on water access were set as a priori indicators in reviewing validity testing of scales. However, any other food- and health-related indicators used for validity testing were also extracted for review and summarization. Specifically, actual scales were reviewed to ensure that accurate synthesis occurred in assessing the key dimensions of the scales.

### Description of the studies

The 8 full text articles included in the review were published between 2009 and 2018 (18–25). Five studies were conducted in sub-Saharan Africa (18–21, 24), 2 were conducted in North and South America (23, 25), and 1 was conducted in South Asia (22). All 5 sub-Saharan African studies were conducted in rural areas and represented countries of Ethiopia (20, 24), Kenya (18), Lesotho (19), and Uganda (21). The remaining 3 studies conducted in urban and peri-urban areas were from Bolivia (25), Nepal (22), and the United States (23).

As shown in **Table 1**, the majority of the studies were conducted specifically with women (18, 20–22, 24) based on the assumption that they are generally responsible for fetching and managing water for the household. All the studies used the convenience sampling method and generally involved the mixed-method approach to develop and/or test the scale. As shown in Table 1, 5 of the 8 studies (18, 19, 23–25) included preliminary qualitative and ethnographic assessment—that is, a formative phase to collect detailed information on water-related behaviors and lived experience of water insecurity in the study community. Formative methods such as free listing, focus group discussions, in-depth qualitative interviews, and direct observations were used (Table 1). In 3 instances, previously developed water insecurity (20, 22) and food insecurity (21) scales were adapted to develop and test the scale in the study area. During the formative phase, in several studies, local bilingual community health workers or local social service providers were consulted, and efforts were made to make scale culturally relevant and appropriate for the study community. For example, Jepson (23) consulted *promotoras*—bilingual community health workers, fluent in English and Spanish—to ensure that word use, questions, and methodology used were culturally appropriate and relevant for the study community.

### Results of testing and validation of scales

Studies used a range of water- and health-related indicators for validity testing, including the 4 UN-Water standards on water access. Due to a lack of established definition and gold standard measure to assess water insecurity at the household level, indicators were used inconsistently for different validity testing. Hence, in this review, without any specifications on types of validity tested, a general term of validation is used. The validation results are presented in the following section and summarized in **Table 2**.

### Validation testing using a priori 4 UN-Water standards on water access

***Amount of water use.***

This indicator was used most commonly (18, 20–22, 24, 25), but its measure and data collection methods varied among studies. The measure ranged from amount of water use per household member to amount of water stored in the house and general perception of access to a sufficient amount of water. Results on association between water insecurity and water use/water collected were mixed, with generally either negative or no correlation found. In rural studies in sub-Saharan Africa, the results showed no statistically significant correlation between water insecurity and the amount of water

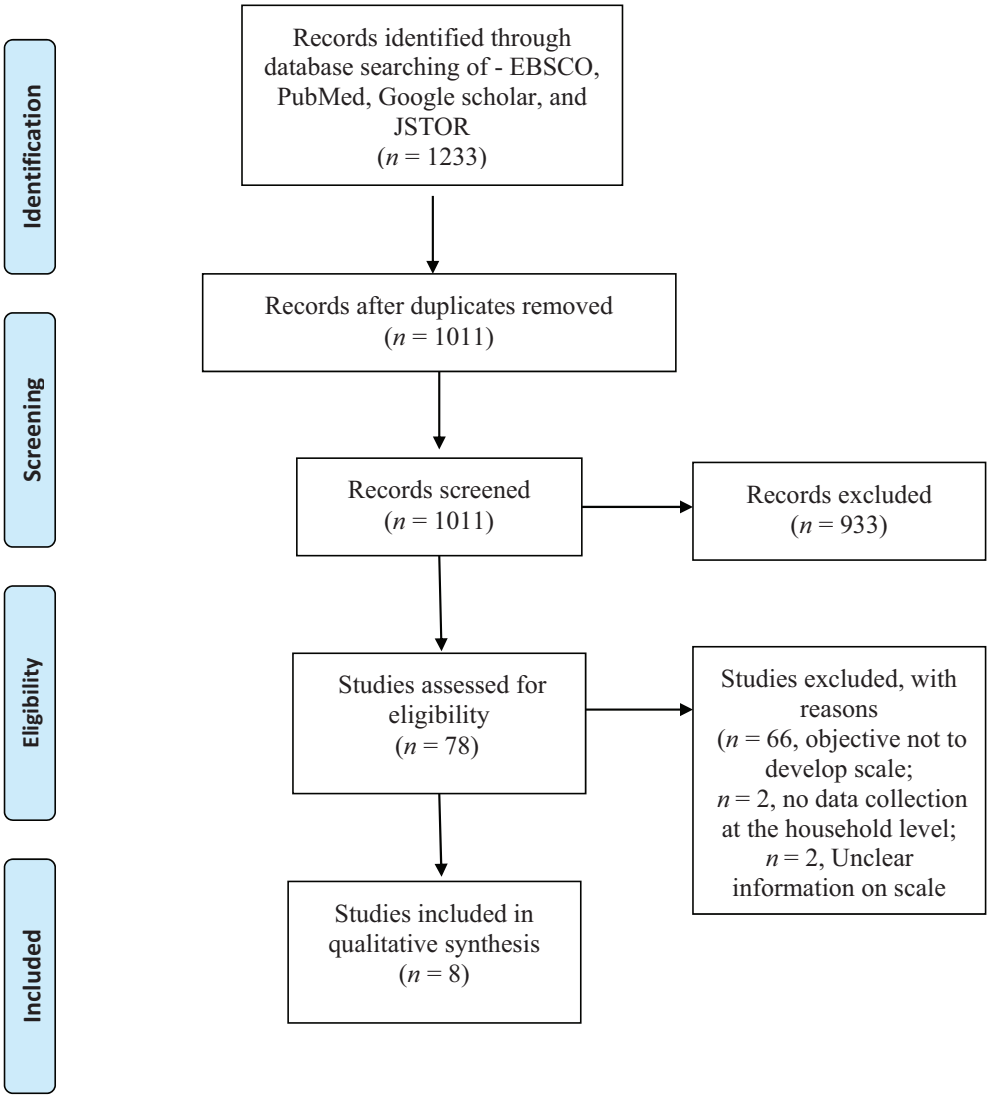


**FIGURE 1** Description of the search process and selection of articles for review using the recommended PRISMA approach. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

use. In Uganda, Tsai et al. (21) measured daily water use at the household level by asking participants about the total number of small (5 L), medium (10 L), and large (20 L) jerry cans of water used per day and found no correlation ($r = 0.03$; 95% CI: −0.08, 0.14). Similarly, the study conducted in Kenya showed no correlation between water insecurity and per capita household water use ($r = 0.12$; $P = 0.193$) (18). Studies conducted in Ethiopia reported a quantity of water collected per person ranging from 10 to 12 L (24) and an average self-reported per person daily water use of 13.7 L (20), significantly lower than the minimal standard of 50 L. However, in both cases, no significant association was found between water insecurity and the amount of water collected ($r = -0.01$; $P = 0.82$) (24) and the amount of water used ($r = 0.02$; $P$-trend $< 0.35$ ) (20), respectively. Even when water insecurity was compared with a specific behavior such as the frequency of bathing children, an indicator of amount of water use, no significant relation was found (20).

Specifically, a significant negative relation was found between water insecurity score and perception of water sufficiency for general daily needs. In the Ethiopian study, those who rated high on water insufficiency were more water insecure than those who perceived that water available for their households was sufficient ($P$-trend $< 0.0001$) (20). In fact, in the study conducted in urban Bolivia, no significant association was found between diary data on daily water use and water insecurity ($P = 0.11$). However, when water insecurity was compared with the self-reported estimates on daily water use (collected using free recall and prompted recall), a significant negative correlation was found (free recall: $r = -0.32$; $P = 0.006$; prompted recall: $r = -0.36$; $P = 0.002$). In an urban study in Nepal (22), a moderate

**TABLE 1** Description of the study characteristics and formative phase conducted to develop water insecurity scales at the household level from 2000 to 2018

| Reference | Study location | Setting (rural vs. urban) | Study period[1] | Scale development process | Sample size[2] (*n*) | Participant characteristics (age, gender, other characteristics) |
|---|---|---|---|---|---|---|
| Boateng et al. (18) | Nyanza region, southwestern Kenya | Urban, peri-urban, and rural | June 2015 to August 2016 | Photovoice, go-along interviews, Delphi method, FGD, and cognitive interviews | Photovoice, go-along, and FGD: $n = 40$; cognitive interviews: $n = 10$ | Mean age: 25 y; postpartum women of mixed HIV status |
| Workman and Ureksoy (19) | Maseru District, Lesotho | Rural | February–November 2011 | Literature review and in-depth structured qualitative interviews focused on water access, availability, usage, safety, and sanitation | $n = 56$ | Mean age: 51 y; both male and female, generally head of the household |
| Hadley and Freeman (20) | 18 different counties, Ethiopia | Rural | October and November 2011 | Previously developed water insecurity scale was adapted | NA | NM; female head of the household or another member |
| Tsai et al. (21) | Mbarara District, Uganda | Rural | June 2014 to February 2015 | Used the Household Food Insecurity Access Scale by Swindale and Bilinsky to create similar statements in reference to water access and use | NA | Median age: 31 y; women of reproducible age in a household with a child younger than age 5 y |
| Aihara et al. (22) | Kathmandu Valley, Nepal | Urban | January–March 2013 | Scale based on the literature and previous scale development study by Stevenson et al. (24) | NA | Mean age: 31 y; adult women |
| Jepson (23) | Hidalgo County, Texas | Peri-urban | January 2009 to August 2012 | Semistructured interviews; consultation with 5 *promotoras* and 8 additional local residents on the length, structure, language, and relevance of the scale items | $n = 40$ | NM; men and women, generally female head of the household |
| Stevenson et al. (24) | South Gondar zone, Amhara, Ethiopia | Rural | November 2009 to February 2010 | Free listing and ranking, survey, and focus group discussions | Free listing and ranking: $n = 39$; survey: $n = 104$; 3 focus groups: $n = 30$ | Mean age: 39 y; women, head of the household or wives of the head of the household |
| Hadley and Wutich (25) | Cochabamba, Bolivia | Urban | 2004–2005 | Observations, water use diaries, and qualitative interviews | $n = 72$ | NM; men and women, household heads |

[1] Refers to the entire study period, including both formative and scale testing phases. FGD, focus group discussions; NA, not applicable; NM, not measured.
[2] Sample size is specifically in reference to the scale development phase and does not include the testing/validation phase.

**TABLE 2** Summary of testing and validation results of household-level water insecurity scales developed from 2000 to 2018

| Reference | Relation with the 4 UN-Water standards on water access | | | | Psychosocial stressors[3] | Other food- and health-related indicators |
|---|---|---|---|---|---|---|
| | Amount of water use[1] | Water collection time | Distance to water source | Monetary water cost[2] | | |
| Boateng et al. (18) | – (per capita household water use) | +ve | NM | +ve | +ve (perceived stress) | +ve: food insecurity |
| | — | — | — | — | — | WI higher in the dry than in the wet season |
| Workman and Ureksoy (19) | NM | NM | NM | NM | +ve (anxiety and depression) | +ve: poor perceived cleanliness of water |
| | — | — | — | — | — | +ve: food insecurity |
| Hadley and Freeman (20) | – (water use in liters/person) | +ve (overall and by season) | +ve | NM | NM | –ve: handwashing at key times |
| | — | — | — | — | — | +ve: incidence of diarrhea among children |
| Tsai et al. (21) | – (daily household water usage) | NM | +ve | NM | NM | Gender difference noted: higher WI among women vs. men |
| Aihara et al. (22) | –ve (amount of water collected) | –ve (water service hours) | NM | NM | +ve (interaction effect, significant when water service was <7 h/wk) | — |
| Jepson (23) | NM | NM | NM | +ve | NM | +ve: poverty level |
| Stevenson et al. (24) | – (daily amount of water collected per person) | +ve | NM | NM | +ve | — |
| Hadley and Wutich (25) | – (diary report of water use estimates) | NM | NM | –ve (household income level) | +ve | –ve: household income |
| | — | — | — | — | — | –ve: water storage capacity |
| | — | — | — | — | — | WI higher during dry vs. wet season |
| | — | — | — | — | — | +ve: borrowing water from neighbors |
| | — | — | — | — | — | +ve: begging water vendors to sell water |
| | — | — | — | — | — | Gender difference noted: higher WI among women vs. men |

[1] Due to differences in measurement indicators, specific information on what was measured for amount is indicated. +ve, positive association; –ve, negative association; –, no association: all.
[2] Specific standard referred to water cost exceeding 3% of the household budget.
[3] The term psychosocial stressors is used as a broader term representing a range of mental and behavioral health indicators, such as depression, stress, and anxiety, and it is in reference to water insecurity.NM, not measured; WI, water insecurity.

negative correlation was found between water insecurity score and the quantity of water collected for the household ($r = -0.44$; $P$-trend $< 0.001$).

***Water collection time.***

This measure represents mainly 2 time-related indicators—that is, time to reach the water source and queuing time at the source. This measurement was used in 3 sub-Saharan African studies in Kenya and Ethiopia (18, 20, 24). All 3 studies represented a general rural scenario of walking to unprotected water sources such as rivers, wells, or springs. In the study by Hadley and Freeman (20) in Ethiopia, the association between amount of time it took to obtain water and water insecurity was tested overall and separately for dry and wet seasons. As expected, water insecurity overall was positively associated with the average time to fetch water ($r^2 = 0.29$; $P$-trend $< 0.0001$), and it was significant for both seasons. In a similar study performed in Ethiopia by Stevenson et al. (24), spending more than 60 min to reach the water source was very common, and it was significantly related to water insecurity ($r = 0.52$; $P$-trend $< 0.0001$). Boateng et al. (18) measured total time spent per week to acquire water and found a significant positive correlation with water insecurity ($r = 0.41$; 95% CI: 0.23, 0.57; $P$-trend $\leq 0.001$).

In the case of urban studies, water source and arrangement varied from using a communal tap at a nearby location to getting water through private water tankers. Hence, indicators such as queuing time, hours of water service available, and frequency at which a water tanker delivered water to the community were commonly used to estimate time cost in the urban setting. For instance, in the study performed in the United States by Jepson (23), physical access or time required to reach the store to buy drinking water was mainly related to availability of transportation and physical health. Based on the qualitative phase results, it was noted that due to limited mobility, the elderly were likely to spend more time and resources accessing water and were more likely to be water insecure. Also, in this urban setting, more than actual distance, having a personal vehicle predicted the ability to obtain drinking water from a store or water vending station. It was also noted that although participants had access to running tap water, time was a significant variable because the amount of time it took to fill the water storage tank for the household depended on the water pressure. In an urban setting of Nepal (22), limited hours of water service, representing spending excess time and related resources in coordinating the daily schedule to ensure somebody from the household was available to collect water when water service was on, was associated with water insecurity. In this study, less than 4 h per week of water service was associated with higher water insecurity compared with more than 4 h per week of water service ($P$-trend $< 0.001$).

***Distance to water source.***

Similar to the time indicator, in a rural setting, distance to water source mainly referred to walking distance to unimproved water sources of rivers, wells, or springs. In rural Uganda, Tsai et al. (21) measured distance by *1*) direct estimate of distance to water source in meters or *2*) elevation of the path to water source in comparison to household location. In general, participants were living a median distance of 269 m from their primary water source. In the case of elevation, households were located 23 m above the water source. In comparison, both these indicators were significantly associated with water insecurity (distance: $r = 0.16$; 95% CI: 0.05, 0.27; $P$-trend $< 0.05$; elevation difference: $r = 0.20$; 95% CI: 0.10, 0.31; $P$-trend $< 0.05$). In Ethiopia (20), water insecurity was significantly higher among households when the distance to water source was more than 1.5 km (water insecurity score of 0.16 for distance $>1.5$ km compared with $-0.85$ for distance $\leq 1.5$ km; $P$-trend $< 0.001$). Comparison was also made to determine if households that used animals to assist in water collection were protected from water insecurity. In fact, however, the opposite was observed—that is, those who used animals to collect water for the households were more water insecure (water insecurity score of 0.26 for those who used animals compared with $-0.24$ for those who did not use animals; $P$-trend $< 0.0001$). This may indicate that use of animals may be more common for long-distance water sources and hence may represent hardship in water access.

As expected, distance to water source was not used in urban studies because use of natural surface water was not common, and thus distance to water source was not applicable for urban studies. In Bolivia, Hadley and Wutich's (25) description of the study setting indicated that participants had to pay private water tankers to deliver water to their households. It was reported that ~38% of households did not have municipal water service and relied on alternative water sources such as rainwater and buying water from private vendors. In such a case, distance to water source was not an issue, but the opportunity cost was more in terms of planning to be available to meet the water tanker's time schedule. Similarly, in another urban study (22), the water tap in a nearby vicinity was available, but the limited water supply service ranging from 7 h to less than 4 h per week was an issue. Hence, measurement of distance to water source in an urban setting might not be an accurate or valid indicator.

***Water cost exceeds 3% of the household income.***

This indicator was not commonly used for validity testing. Among the 3 studies that used this indicator (18, 23, 25), it referred to money spent directly on buying water from private vendors, paying water bills, or paying somebody to fetch water. In the United States, Jepson (23) found that the cost of water was positively related to water insecurity among residents of "border colonias" in Texas. Results indicated that water insecure households spent 8% of their income in purchasing water compared to 5% spent by water secure households. Furthermore, lack of financial resources to either pay the water bill or purchase water was associated with moderate to high levels of water insecurity. Approximately half of the study participants reported not having money to

pay for water, and two-thirds of the participants affirmed they adapted water use to save money. Hence, direct water cost was noted as a significant predictor for water insecurity. However, Jepson also noted that indirect water cost affected access to water and insecurity levels. For instance, if participants did not have money to buy gas for a vehicle, they were not able to drive to a vending station to purchase drinking water. Hadley and Wutich (25) did not directly measure the cost of water but, rather, investigated the association between water insecurity and household income. As expected, the results showed a significant negative correlation between income and water insecurity ($r = -0.55$; $P$-trend $< 0.0001$), and this pattern was attributed to potential better purchasing power of high-income households to buy water from private vendors. Among low-income study participants, requesting private vendors to give water on credit was common and was associated with water insecurity.

Among rural studies, only Boateng et al. (18) compared the ability to purchase water with water insecurity. Results indicated that amount of money spent on water per month was positively associated with water insecurity ($r = 0.20$; 95% CI: 0.05, 0.35; $P$-trend $\leq 0.01$).

### Validation testing using other indicators

#### *Pyschosocial distress including anxiety, stress, and depression.*

Under the assumption that uncertainty and limited access to clean and sufficient water can also affect behavioral and mental health, most of the scale development studies tested water insecurity with psychosocial measures (18, 19, 23–25). For instance, as shown in Table 2, Workman and Ureksoy (19) measured and analyzed the effect of water insecurity on distress among head of households in a highly HIV-affected area of Lesotho, Africa. High affirmation for limited access to water was associated with increased levels of distress ($\Delta R^2 = 0.047$; $P$-trend $< 0.05$). Aihara et al. (22) compared water insecurity score with perceived stress representing individual sense of control over daily life demands. Interestingly, the results differed by water supply service hours. Those who were living in a very limited water service area of less than 4 h per week showed a significant positive relation between water insecurity and distress. Stevenson et al. (24) also showed a significant positive relation between water insecurity and psychosocial distress among caretakers ($r = 0.22$; $P$-trend $< 0.001$). Boateng et al. (18) found a similar pattern in Kenya—that is, water insecure women were more stressed than their secure counterparts ($\beta = 0.12$; 95% CI: 0.07, 0.16; $P = 0.0001$). Similarly, Hadley and Wutich's (25) validation study indicated a strong positive association between water insecurity and distress-representing emotions such as worry, anger, bother, and fear related to water shortage ($r = 0.77$; $P$-trend $< 0.0005$). In examining the pathways, Hadley and Wutich found the following psychosocial issues related to water shortage: *1*) poor relationship with the partner; *2*) quarrel with neighbors; *3*) arguments with water vendors; and *4*) frequent occurrence of water-related illnesses. Results also indicated that women were more worried about the water shortage and were more water insecure compared with male members of the family ($\eta^2 = 0.583$; $P = 0.02$). This gender difference was also seen by Tsai et al. (21), who conducted paired comparison between men and women of the same households. Men were less affected and were not as water insecure as women (mean water insecurity score: 8.9 compared with 10.3, respectively; $P = 0.03$), demonstrating the potential occurrence of intra-household gender disparity in stress levels due to perceived difference in severity of water shortage (Table 2).

#### *Food security and other health-related indicators.*

In the study by Workman and Ureksoy (19), the water insecurity dimension of perceived cleanliness was found to be correlated with food insecurity. In examining the association between water insecurity and behaviors affecting food utilization, such as frequency of handwashing after defecation and prior to eating, Hadley and Freeman (20) found that water insecure women were less likely to practice handwashing at those key points (Table 2). This was further reiterated by examining the relation between maternal water insecurity and the incidence of diarrhea among young children in the past 2 wk. Multivariate regression analysis indicated that water insecurity was positively associated with incidence of diarrhea among young children in the past 2 wk (OR: 1.18; 95% CI: 1.07, 1.31; $P$-trend $< 0.05$). Furthermore, Boateng et al. (18) demonstrated that household food insecurity increased with an increase in water insecurity ($\beta = 0.37$; 95% CI: 0.08, 0.66; $P$-trend $< 0.05$).

### Description of scale dimensions, individual items, and related information

In the case of dimensions, all 8 scales captured quantity and quality aspects of water. Hence, in this narrative section, the 2 dimensions covered in all the scales (i.e., quantity and quality of water) are described, followed by other unique dimensions. To supplement the narrative, **Table 3** provides information on the number of items, reference period, response options, and related information for each scale.

#### *Quantity.*

For this dimension, statements were focused on the ability to carry out day-to-day activities such as hygiene, cooking, washing clothes, and drinking. For instance, Boateng et al. (18) asked how frequently there was not enough water for garden/crops, to wash clothes, for cooking, to wash hands, to wash children's faces and hands, and to wash the body. The scale also included an item enquiring whether the respondent or other family members went to sleep thirsty. Because the study was conducted in an HIV pandemic region, the scale also included an item on whether there was not enough water to take medications. In another example, Tsai et al. (21) asked if less than needed water was used and also included statements on water intake, such as drinking less water than needed and going to sleep thirsty.

**TABLE 3** Description of the scales developed to measure water insecurity at the household level from 2000 to 2018

| Reference | No. of items | Reference period used[1] | Response options and scoring | Majority dimensions covered | Statements related to daily water intake and food access/intake |
|---|---|---|---|---|---|
| Boateng et al. (18) | 20 | In the past 4 wk | 5-point Likert; continuous | Quantity, quality, social cost/distress | DWI: not been as much water as would like; not enough water to take medication; gone to sleep thirsty; drank unsafe water |
| | — | — | — | — | FAI: time spent fetching prevented from earning money; had to change what was being cooked |
| Workman and Ureksoy (19) | 35 | A typical day | Open questions; NM | Quantity, quality | DWI: drinking (water source, how often, amount used) |
| | — | — | — | — | FAI: cooking (water source, how often, amount used) |
| | — | — | — | — | Watering garden (water source, how often, amount used) |
| Hadley and Freeman (20) | 21 | In the past 30 d | Yes/no; continuous | Quantity, quality, social cost, safety issues | DWI: whole day without drinking water; go to sleep thirsty |
| | — | — | — | — | FAI: not cook a desirable food |
| Tsai et al. (21) | 8 | In the past 30 d | 4-point Likert; continuous | Quantity, quality | DWI: drink water from undesirable source; drink unsafe water; drink less water than needed; go to sleep thirsty |
| Aihara et al. (22) | 20 | In the past 30 d | 5-point Likert; continuous | Quantity, quality, social cost, health issue | DWI: difficulties in drinking |
| | — | — | — | — | FAI: Less time for daily work and income generation activities; reduced work efficiency due to water-related health problems; difficulty cooking |
| Jepson (23) | 19 | In the past year | Yes/no; categorical | Quality, water distress | DWI: tap water is visually unclean; tap water has unpalatable taste or smell |
| | — | — | — | — | FAI: water >2.5% monthly cash income |
| Stevenson et al., 2012 (24) | 24 | In the past 30 d | Yes/no; continuous | Quantity, quality, social cost/distress | DWI: went to sleep thirsty; went a whole day without drinking water |
| | — | — | — | — | FAI: did not cook a desirable food |
| Hadley and Wutich (25) | 9 | In the past week | Yes/no; categorical | Quantity | DWI: NM |
| | — | — | — | — | FAI: unable to cook a meal; conserve water to cook |

[1]The period mentioned is as reported in the scale. DWI, daily water intake; FAI, food access/intake; NM, not measured.

***Quality.***

Similar to quantity, all the scales had 1 or more statements enquiring about perceived safety and cleanliness of water. Water quality issues were enquired through respondents' perceptions of water color, taste, and source of water. Workman and Ureksoy (19) asked directly about the perception of cleanliness of water. Jepson (23) included a series of questions on water quality, ranging from enquiring whether participants believed that the tap water made someone in the household ill to whether it was visually unclean, including whether the tap water was unpalatable by taste or smell. Similarly, Hadley and Freeman's (20) and Stevenson et al.'s (24) scales included items asking whether participants believed that the water they drank was unsafe. Boateng et al.'s (18) scale included statements asking how frequently participants wanted to treat (by boiling or using chemicals) their water but could not. The number of questions or statements on water quality ranged from 2 to 5 for different scales.

***Other dimensions commonly included: time and other opportunity costs, social distress, food-related issues, and water intake behaviors.***

In reference to capturing opportunity costs as a result of poor water access, Stevenson et al.'s (24) study included a subsection enquiring about various social, economic, and time-related costs that households had to incur due to water shortage. For instance, capturing social cost, one of the items included was "Did not participate in church/funeral/wedding/kebele meeting because there were too many chores to do." Similarly, in Hadley and Freeman's (20) study, statements enquiring if participants consumed undesirable food, slept less, or did not attend a social event due to lack of water were included in the final scale. Aihara et al. (22), in reference to the urban setting of communal tap as a source of water for households, included in their scale several statements enquiring about social issues, such as dispute with neighbors and family members, reducing socialization due to water access issues, and whether there was less time for

daily work and income-generation activities due to water collection.

Ultimately, 6 of 8 scales included items enquiring about changes in daily water intake (Table 3). For instance, Stevenson et al. (24) included 2 questions asking if participants went to sleep thirsty and went a whole day without drinking water. Similarly, Tsai et al. (21) asked if participants or anybody in the household drank less water than needed, and they also directly asked if household members went to sleep thirsty because there was no water.

In reference to food security, the statements that had high response rates and were relevant to water insecurity dimensions by statistical testing concerned ability to cook, eat, and prepare desirable foods. However, statements on ability to grow food—another indicator of food security—were not found to be significant and were dropped from the final scale for 2 studies. In Boateng et al.'s (18) study, for instance, statements on not having enough water for garden/shamba or crops or to give to animals or poultry were not maintained. Similarly, in Stevenson et al.'s (24) study, reduced watering of vegetables, staple crops, and livestock all had low response rates and were removed from subsequent scale development.

## Discussion

Overall, significant effort has been made in both rural and urban areas to develop household-level water insecurity scales. All the scales included in our review were tested for various types of validity, including using UN-Water standards on water access. Consistent with the review by Jepson et al. (16), we found that psychosocial distress and anxiety were consistently associated with water insecurity, highlighting the importance of establishing a household-level water insecurity scale, especially to capture the negative effects of the "inconsistent" aspects of the issue that cannot be captured by standard measures, such as the nature of the water source and the distance to the water source. Our results show that dimensions of compromise on quality and quantity of water represent the cornerstone of measuring water insecurity at the household level. For quantity, items enquiring about reduced water use for daily chores contributed significantly to measuring the concept. Reduction in water intake was also a significant item and was retained in all the scales, concluding that dehydration and related health issues are highly possible in water insecurity. No scale tested or made attempts to group participants by severity, but it is assumed that reduced intake of water occurs at the severe stage of water insecurity. Regarding the quality dimension, the statements included were about visual perception of cleanliness of water, use of unsafe sources of water, and whether water drank caused sickness. The results of our review show that water insecurity scale development is important to endorse water as an essential nutrient and accurately estimate the gravity of water shortage and its consequences. This review also highlights the importance of addressing water insecurity to reduce food insecurity and malnutrition among children in a long term.

### Strengths and limitations of the review

To measure water shortage and access issues, several environmental techniques are used, including the Water Poverty Index (13). However, this narrative review specifically provides the current status of research in the development of household-level water insecurity scales. To our knowledge, this is the first review that describes the associations between household water insecurity and the 4 UN-Water standards established to assess and monitor progress in achieving SDG 6 on water and sanitation. However, notwithstanding the limitation of being restricted to English-only articles, this review represents the status of research in measuring water insecurity at the household level.

In validity testing, various water-related indicators were used, including UN-Water standards on water access. Specifically, the UN-Water indicator of amount of water use was commonly used in validity testing. However, its relation with water insecurity was not significant in most of the studies. This might be due in part to differences in the measure used for the amount of water, which ranged from number of jerry cans used to collect water to self-report on liters of water collected daily. Furthermore, all the studies relied on self-report data, which are generally subject to reporting bias. For instance, water recycling/reutilization to optimize its use before the final discharge is a very common practice within water-scarce communities, affecting accuracy of daily water use. Moving forward, it is critical to use more objective indicators for validity testing, such as direct observation on availability of water at the household level. Results of our previous study with rural women in Cameroon indicated that water insecurity was positively associated with the amount of water available at the household level (26). Furthermore, for quality testing, use of microbial indicators, such as the presence and concentration of fecal coliform, will help in testing scale validity objectively and understanding how water insecurity is related to chronic enteric inflammation—a critical indicator of food utilization and growth among children. One study in our review (21) tested coliform count in water and found a positive relation with the water insecurity score.

### Implications of key findings and next steps

A valid and reliable scale to measure water insecurity at the household level is critical not only to make progress on water and sanitation SDG but also to help address goals related to hunger, gender equity, and malnutrition among children. Based on the current research, it can be concluded that quantity and quality dimensions of water are significant for the scale. Considering the successive nature of this research area—that is, investigators have used previous studies to further refine the scale—the most recent validation study and its final scale by Boateng et al. (18) represent the latest version of the household-level water insecurity scale. In further advancing water insecurity scale development, use of objective indicators such as daily intake and microbial testing of water is needed, using predefined sample size and selection criteria. Use of these objective indicators will be time- and

resource-intensive. Hence, learning from the development of food insecurity scales and support from international health agencies, policymakers, leaders, and governments will be critical to prioritize and develop accurate scales to measure water insecurity at the household level. For instance, in reference to food insecurity scale development, support from several health organizations and country leaders has led to the availability of standard, validated scales to measure food insecurity at the household level. The development of the Household Food Security Survey Module by the USDA (27), the scale development promoted by Food and Nutrition Technical Assistance II, and the recently launched scale by the FAO (14) have led to the establishment of a gold standard in measurement of self-reported food insecurity at the household level. Similar funding and support from health organizations and governments are needed for the development of a standardized household water insecurity scale. Advancement in water insecurity measurement will occur with the development of a specific script and step-by-step description of how to use the scale, including training materials to assist standardized data collection by fieldworkers. Further advancement is also needed in establishing a standardized scoring system and cross-cultural acceptability of the scale. Establishment of a standardized scale and its scoring will help in the estimation of different levels of severity and in the evaluation of water interventions, programs, and policies. Specifically, the WASH initiative, which was launched to prevent and address diarrhea and malnutrition among children, is based on improving access to clean and adequate amounts of water—that is, reducing water insecurity (2). Hence, it is logical to include water insecurity measurement in estimating the effectiveness of the WASH intervention.

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